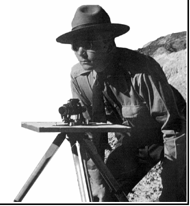
GEOLOGIC RESOURCE MONITORING PARAMETERS

Sediment sequence and composition



Brief Description: Lakes, wetlands, streams (and overbanks), estuaries, reservoirs, fjords, shallow coastal seas and other bodies of marine or fresh water commonly accumulate deposits derived from bedrocks, soils, and organic remains within the drainage basin, though fine particles can also be blown in by winds from distant natural, urban and industrial sources. These aquatic deposits may preserve a record of past or on-going environmental processes and components, both natural and human-induced, including soil erosion [see soil and sediment erosion; wetlands extent, structure and hydrology], air-transported particulates [see dust storm magnitude, duration and frequency], solute transport, and landsliding [see slope failure].

Some of these bodies of water are dynamic and sensitive systems whose sedimentary deposits preserve in their chemical, physical and biological composition a chronologically ordered and resolvable record of physical and chemical changes through their mineralogy, structure, and geochemistry (e.g. organic C, biogenic silica, stable O isotopes in carbonates and cellulose, trace metals) [see surface water quality]. Of particular value in determining long-term data on water chemistry are the remains of aquatic organisms (e.g. diatoms, chrysophytes, chironomids, and other algae and invertebrates) which can be correlated with various environmental parameters. In addition, fossil pollen, spores, and seeds reflect past terrestrial and aquatic vegetation. Sediment deposits can, thus, provide an indication of the degree and nature of impact of past events on the system, and a baseline for comparison with contemporary environmental change.

Some lakes (and reservoirs) are open systems characterized by relatively stable shorelines and a limited residence time for solutes; others are closed (endorheic) and/or ephemeral (playas). Lake water solute concentrations may range over five orders of magnitude from dilute, monsoonal rainwater to viscous chloride brines of 500,000 mg/kg; the pH may range from less than 2 in some sulphuric-acid rich Japanese crater lakes to more than 11 in alkaline brines of the East African rift.

Significance: The chemical, physical and biological character of aquatic sediments can provide a finely resolvable record of environmental change, in which natural events may be clearly distinguishable from human inputs.

Environment where Applicable: Any depositional environment (e.g. lakes, ponds, estuaries, river bottomlands, lagoons, bays, fjords) where water permits the accumulation of sediment. River deposits can preserve useful records, but the precise source and environmental context of fluvial sediments are commonly uncertain, except for those in oxbow lakes and meander cut-offs [see stream sediment storage and load].

Types of Monitoring Sites: Topographic lows which are open water or wet over the long term. Especially valuable are deposits in lake basins with no outlets, confined basins with low inflows, and rain-fed peatlands.

Method of Measurement: Surface sediments collected by gravity corers, grab sampling or dredging are useful for measuring the status of prime indicators, and may represent the last decade or so, depending on the local accumulation rate. Surficial deposits are commonly very loose and hard to collect: special sampling devices may be required, such as tubes filled with dry ice on which a thin skin of sediment is frozen and kept stratigraphically coherent. Sediment cores obtained by piston coring, or drilling from barges or from winter ice are used to determine the long-term environmental background. A chronology can be established by measuring unstable isotopes (e.g. 210Pb, 137Cs), datable tephra layers, or fossil content. There are standard methods of geochemical and limnological analysis that characterize individual layers which can, in turn, be dated through a variety of methods. Shipborn acoustic and seismic investigations can be helpful in establishing stratigraphic sequences.

Important parameters include humification, mineral content, magnetic susceptibility, major element, trace element and stable isotope geochemistry, specific pollutants (e.g. DDT), biogenic silica, fossil remains, and biochemical markers such as photosynthetic pigments from blue-green algae. Many of these indicators can be related to environmental variables using quantitative transfer functions. For example, biotic fractions, such as diatoms, can provide direct or proxy data on pH, total lake phosphorous, temperature and salinity. Spores and pollen grains can reveal past vegetation patterns. Diagnostic indicators of human activity found in sediments include: pollen or seeds of cultivated plants; fly-ash, charcoal, soot and oil particles from coal or oil-fired power stations and industrial and domestic sources; high concentrations of heavy metals (such as Pb from leaded fuels and paints), artificial radionuclides, and derivatives from fertilizers and pesticides; and geochemical gradients related to acidification.

Frequency of Measurement: At least every five years. In the case of modern sediments, which are expected to reflect environmental changes within a drainage basin or sediment catchment, sampling may be carried out at monthly, yearly or longer intervals, depending on the rate of deposition.

Limitations of Data and Monitoring: The degree of resolution of past records depends on deposition rates and sediment preservation, and on the ability to establish a detailed chronology. This can be difficult, for temporal and spatial resolution of the record are controlled by properties of the accumulating system. In some lakes, sediments are continuously deposited, whereas others, such as playas, dry out periodically and are less useful as a source of paleo-data. Fluvial sediments, particularly in estuaries, may preserve a record of environmental changes, but river systems tend to be more open than lacustrine. There are also problems with processes that affect organisms after death (taphonomy) and sediments after their initial deposition, such as bioturbation and diagenesis. The ecological optima and tolerances of some indicators are poorly understood. For example, trace element profiles may reflect human inputs or a natural redistribution in response to redox potential within the water column.

Possible Thresholds: A critical load or threshold may be crossed when the concentration of pollutants changes the structure or function of aquatic ecosystems.

Key References:

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Related Environmental and Geological Issues: Paleoenvironmental data from sediment deposits can provide a record of the impact of distant human activity (e.g. burning of fossil fuels or the release of chemicals) on the wider ecosystem. They can be invaluable in environmental management by providing a baseline for management decisions within a watershed.

Overall Assessment: The chemical, physical and biological composition of sediment sequences provides one of the best natural archives of recent environmental changes in terrestrial and aquatic systems.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.